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SPEEDING UP FLOWERING IN THE DAFFODIL AND THE BULBOUS IRIS

By David Griffiths,[1] *senior horticulturist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry*

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INTRODUCTION

Only the essentials of studies dealing with the effect of storage temperatures on the flowering of daffodil and iris stocks, extending over a period of 6 or 7 years, are recorded in this circular. Early in the investigations hundreds of tests were made to determine the apparent optimum treatments. This report contains an account of only a few selected experiments which demonstrate the behavior of stocks subjected to the treatments designed to flower them early or preserve them for opening later than the dates at which it is customary to flower them when planted at the usual season.

From time to time during the progress of the work dealing with methods of reducing the time between the planting and the flowering of daffodils and iris under forcing conditions, preliminary announcements were made in scientific and trade papers, as occasion seemed to warrant, so that the main theses have been made familiar to growers as the work progressed. Inasmuch as some forcers took advantage of the method of cold treatment following the reports of the early experiments, the general matter of acceleration has become common practice almost simultaneously with the development of the investiga-

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tion, and some growers have had experience with advancing the flowering of their stocks for practically the same period that these investigations have continued. Many of the details recorded here on early flowering are therefore familiar to and practiced by growers, but those relating to late forcing are not so well known.

STOCKS USED

The daffodil bulbs used in the investigations were in the main comparatively old American stocks. The most ancient in point of residence is Double Van Sion, which was imported into Virginia from the Guernsey Islands over 40 years ago by the Huberts. Victoria and Sir Watkin were imported by the United States Department of Agriculture between 1906 and 1910. Nearly all the King Alfreds employed were from an importation made to the United States Bellingham Bulb Station, Bellingham, Wash., in 1917. The Golden Spurs used were imported about 1920. The stations at Rosslyn, Va., Willard, N. C., and Charleston, S. C., mentioned later, were stocked with bulbs from Bellingham.

The stocks forced were, therefore, of uniform origin, practically all the bulbs of a variety being from single importations made 12 to 40 years ago, propagated at the Bellingham Bulb Station, and then supplied from there to the stations in the other States. The period of culture in the different States is variable, of shorter duration, and unrecorded. King Alfred bulbs especially were shipped to the other stations at frequent intervals, it being difficult to keep up stock mainly on account of the large demand for this variety from these warmer, long-season locations. The investigations, therefore, cannot be looked upon as furnishing any basis for an estimate of the permanent quality of the stocks in any but those from the Bellingham Bulb Station.

All the stocks for these forcing investigations, except where otherwise noted, were produced under the writer's immediate direction, but with the close cooperation of men in other organizations in the Department of Agriculture. The Bellingham Bulb Station is operated for bulb investigations only. The Arlington Experiment Farm, Rosslyn, Va., is also operated by the Department, bulb investigations being one of its various activities. The bulbs from Willard, N. C., were produced on the Coastal Plain Station of the North Carolina Department of Agriculture. The station on James Island, near Charleston, S. C., was operated by the Department through the Division of Cotton and Other Fiber Crops and Diseases. When reference is made in the text and tables to these different stocks it is by using the abbreviated name of the station, the city near which it is located, or perchance simply the State.

All cold-storage treatments except where otherwise stated were applied at the cold-storage laboratories on Arlington Farm.

The conditions under which the stocks used in the tests were produced were quite diverse, varying from the optimum of Puget Sound with its low temperatures and high humidity during the growing season to the extreme mildness obtaining at Charleston, S. C. The Virginia and North Carolina situations represent median conditions, but both are milder than many daffodil-producing sections, such as New York, Michigan, or Tennessee.

At the Bellingham Bulb Station the soil is a heavy silt loam underlain with clay, requiring careful preparation in order to get rid of the surplus moisture, although the rainfall is only about 35 inches a year. The Virginia situation has an artificial make-up, a swamp filled with dredgings from the Potomac River, varying from a coarse sand to a fine silt which clods rather badly. In North Carolina the fine sandy loam is underlain by a yellow, stiff, sandy clay. The South Carolina location is quite typical of southern sands.

METHODS OF ACCELERATING FLOWERING

A number of methods may be employed to accelerate the flowering of daffodils and other bulbs. The so-called "forcing process" is in itself a process of acceleration dependent on the control of heat, light, and moisture to better advantage than obtains under field conditions.

EARLY DIGGING

First-class daffodil bulbs may be dug 3 weeks before they are usually considered ripe, with some sacrifice of growth and firmness but with a measure of acceleration of flowering the next season. Indeed, on several occasions in the last few years daffodil bulbs dug from beds as soon as the flowers had faded have blossomed fully under field conditions the following year with an inflorescence that would ordinarily pass for normal. Under forcing conditions these early-dug bulbs may be blossomed somewhat earlier than when they are allowed to mature in the soil. In order for flowering to be satisfactory following early digging, the stocks must be of prime quality.

GROWING IN AN EARLY REGION

Another way of causing daffodils to flower earlier is to produce them, or at least grow them, 1 year in a region where they mature early. The earlier they mature the sooner they are ready to grow again the following season. The early daffodils, such as Golden Spur and Minister Talma, can be dug in North Carolina the middle of May, and King Alfred and Sir Watkin by June 1. At the Bellingham Bulb Station it is seldom that daffodils can be dug before July 1. The North Carolina bulbs, consequently, can be forced earlier than those from Bellingham.

In Europe there was a time when stocks were actually transported from the Netherlands to the early region of southern France to be prepared for early forcing by 1 year of culture there. It was the custom to grow Golden Spur and Victoria stocks in the Netherlands except the last year, when they were grown in southern France. There is abundant opportunity for this sort of treatment in the United States.

STORAGE TEMPERATURE MANIPULATION

The next method of acceleration is dependent upon a manipulation of the temperatures during the storage season from June to September and is the one mainly treated in this circular. The procedure followed at the present time to cause early flowering has been arrived at after many trials and is very simple. Reduced to its low-

est terms, it consists in subjecting the bulbs to be forced to ordinary warm storage conditions of the region where grown until about 4 weeks before potting and then to 50° F. for the remainder of the storage period. Since the temperatures in ordinary storage in the eastern United States are not far from the optimum for this early process, the bulbs in commercial practice are almost invariably left in common storage up to August and then put in 50° for a month before planting. Just why this manipulation of temperature should shorten the time necessary to bring the plants into flower has not been demonstrated so far as known.

A brief discussion of investigations leading to the establishment of the methods of procedure now more or less in vogue in the early flowering of daffodils and iris follows.

EARLY FORCING OF DAFFODILS

LOW TEMPERATURES DURING ENTIRE STORAGE SEASON

A number of years ago an attempt was made to determine the best storage conditions for the preservation of daffodil stocks in the warmer daffodil-growing sections of the United States. In the course of these researches some important facts were brought out with reference to the effect of the storage temperatures on the subsequent behavior of the bulbs in the field and in the greenhouse. The quickening effect of subjection of the bulbs to comparatively low temperatures in storage was surprising to both growers and florists.

The behavior of bulbs stored at various temperatures for the entire storage season may be illustrated by observations on Van Waveren's Giant. Virginia-grown bulbs were placed in 36°, 40°, 50°, 55°, 60°, and 70° F. temperatures as soon as the surface dried, which took about 2 days after digging, June 6, and remained in those temperatures until potting, September 22. After being planted in pots or flats the bulbs were set away in a cellar, where the temperature fluctuated from 55° to 65° most of the time. On November 13 all the flats were put on the benches of an unheated greenhouse until November 22, when the night temperature was set at 50° to 55°, and on December 6 it was put up to 60° to 65°. Storage conditions with both high and low relative humidities of approximately 90 and 75 percent, respectively, were available at both 40° and 50°, so lots of bulbs were subjected to the two conditions at these two temperatures and to low humidity only in the others. There was uniformly too much root action in the high humidity.

The behavior of the forced bulbs was evaluated on December 26 as follows:

At 36° F. No growth of either tops or roots. Bulbs were firm and sound.

At 40° (low humidity). One bulb only made 1 inch of growth, but there was a little rooting in all of them.

At 40° (high humidity). Every bulb making a short spindly growth and some roots but no flowers.

At 50° (low humidity). First flowers December 20, detrimentally dwarfed, but every bulb flowering.

At 50° (high humidity). First flowers December 24, with quality and growth as from the 50° low humidity.

At 55°. First flowers December 26, subnormal but more robust than from 50°.

At 60°. Plants 6 inches high, flower spike not visible.

At 70°. More backward than from 60°.

Check (from bulb house with uncontrolled temperature). Only 1 inch of top growth; did not blossom until the last of January.

The series of tests showed inhibition of growth at 36° F., dwarf growth with inhibition of flowering at 40°, complete accelerated flowering of excessively dwarfed plants at 50° and 55°, some acceleration with less dwarfing at 60°, and less of both acceleration and dwarfing at 70°. None of the treatments proved desirable, for the satisfactory acceleration at 50° was accompanied by too much reduction of growth.

A number of varieties were handled with Van Waveren's Giant under the same storage, rooting, and forcing conditions. The reactions were very similar in principle, but varied somewhat in minor details. The dwarfing effect of the cold treatments for the entire storage season on King Alfred and Victoria is well brought out in plate 1.

The effect of two constant low-humidity storage temperatures compared with the checks from ordinary storage in the bulb house is readily gleaned from table 1, which omits all reference to dwarfing effects, being designed to portray the single idea of the effect of storage temperatures for the entire season on the date of flowering. The date on which the bulbs were put in constant storage temperatures varied somewhat on account of the difference in the digging dates. In addition, the Washington-grown bulbs had to be shipped across the continent to be stored in Virginia.

TABLE 1.—*Comparative dates of flowering of 5 daffodil varieties grown in 3 sections and subjected to 3 storage conditions for the entire season*

Variety	Where grown	Date of flowering after a storage temperature of—		
		50° F.	60° F.	Check (ordinary storage)
King Alfred	North Carolina	Dec. 4	Dec. 22	Dec. 31
Do	Virginia	Dec. 12	Dec. 26	Jan. 3
Do	Washington	Dec. 31	Jan. 15	Feb. 1
Golden Spur	Virginia	Dec. 12	Dec. 26	Jan. 15
Do	Washington	Jan. 4	Jan. 22	Feb. 13
Spring Glory	Virginia	Nov. 30	Jan. 2	Jan. 26
Victoria	North Carolina	Nov. 22	Dec. 11	Jan. 12
Do	Washington	Jan. 29	Feb. 13	Feb. 27
Double Van Sion	do	Dec. 31	Jan. 19	Jan. 28

Table 1 in every case shows the greatest acceleration from the 50° F. storage. Since all flats were subjected to identical conditions after planting, the progressively later flowering from south to north is demonstrated.

In connection with this and subsequent tables and discussions it should be noted that a demonstration of earliest flowering has not been attempted. The consistent purpose has been to get comparability of flowering from the storage treatment used.

LOW TEMPERATURES LATE IN STORAGE SEASON

The effect of low temperatures on the flowering and growth of the plants when applied to the bulbs for the entire season having been determined, the effect of shorter periods of cold treatment was studied for the purpose of obviating if possible detrimental dwarfing evidently resulting from the long-continued cold application. Attention

was focused in the trials on a comparison of the dates of flowering with the approximately normal growth. A method of handling in forcing that was calculated to give this comparison as justly as possible was adopted.

The Virginia-grown bulbs for the trials were held on the ordinary bulb-house shelves under the natural temperatures of the locality from digging to August 15, when they were placed in the constant temperatures, as given in table 1, under refrigeration at the cold-storage laboratory at Arlington Farm. Those from the Carolinas were shipped to the Arlington Farm bulb house in early June after being surface-dried for a few days. The Bellingham stocks remained in the bulb house at Bellingham until August 1 and were then shipped to Arlington Farm to go into constant storage temperatures with the rest on August 15.

Potting was begun September 21 and was completed in 3 days, but no bulbs were wet down until all were in the soil on the 23d. This period of planting the bulbs is referred to as September 22. The rooting cellar was a concrete half-basement where the potted and flatted bulbs were placed on shelves and thoroughly wet on September 23.

The weather was very warm in late September and early October, and the temperature in this heeling ground frequently reached 70° F. in the daytime. After 2 or 3 weeks, however, it fluctuated from 55° to 65°.

The rooting period extended to November 16, when all stocks were transferred to the benches at a night temperature of 45° to 50° F. On November 28 this was increased to 50° to 55°. It was not possible this season to keep the greenhouse temperature below 70° during the day, and it sometimes reached 80°.

Out of several hundred tests made for the purpose of determining the effect of cold treatment during the latter part of the storage season, the 13 series detailed in table 2 have been selected as being representative of the general reactions. The date of planting (Sept. 22) was found from subsequent experiments to be about 3 weeks later than the optimum for early forcing.

TABLE 2.—*Effect of cold treatments from August 15 to September 22 on the flowering of a number of daffodil varieties produced in various sections*

Variety	Where grown	Date of flowering after a storage temperature of—			
		40° F.	50° F.	60° F.	Check (ordinary storage)
Double Van Sion	Washington	Dec. 23	Dec. 29	Jan. 7	Jan. 29
Glory of Sassenheim	North Carolina	Dec. 18	Dec. 24	Jan. 25	Do.
Do	Virginia	Jan. 10	Jan. 21	Feb. 1	Feb. 8
Golden Spur	do	Dec. 22	Dec. 22	Jan. 8	Jan. 19
King Alfred	South Carolina	----------	Dec. 7	----------	Jan. 2
Do	North Carolina	Dec. 19	Dec. 20	Jan. 8	Jan. 12
Do	Washington	Dec. 31	Jan. 17	Feb. 12	Feb. 15
Minister Talma	North Carolina	----------	Dec. 13	----------	Dec. 30
Plato (Krelage)	do	----------	Dec. 31	----------	Jan. 12
Sir Watkin	do	Dec. 22	Dec. 26	Jan. 20	Feb. 8
Do	Virginia	Jan. 8	Jan. 13	Jan. 22	Jan. 28
Vanilla	North Carolina	Dec. 15	Dec. 21	Jan. 7	Jan. 15
Victoria	do	Dec. 24	Dec. 25	Jan. 18	Jan. 19

A, King Alfred daffodils, North Carolina grown. Upper left, stored in commercial cold storage from June to September 22 at 45° to 50° F.; at right, at 55° to 62°; in front, at 34° to 36°. Photographed January 10. The forcing was identical with *B*. *B*, Victoria daffodils, North Carolina grown. At left, stored at 34° to 36° F. from June to potting time, September 22; at right, stored at 55° to 62° for the same period. The pot in front is the check from ordinary storage. All were rooted in a cellar at about 55° to 65° from September 22 to November 16, when they went on the benches at 45° to 50° at night to November 28, when the temperature was raised to 50° to 55°. Photographed January 17.

A, King Alfred daffodils, North Carolina grown, all stored from digging time to August 15 in normal storage. Then those at left were put in 50° F. storage until planting time, September 22, while check on right remained in ordinary storage until planting. Those at left exposed to 50° prior to planting were rooted in the cellar at 50° to 65° to November 16, when they were benched at 50° to 55° at night to November 28, and then at 55° to 60° and began to flower December 20. Photographed December 27. *B*, King Alfred daffodils, Arlington Farm grown; those in center carried in ordinary storage to August 15, then at 50° to planting October 15; blossoming began January 15; photographed February 27, after 50 to 75 flowers had been cut. Those on right and left from ordinary storage. Grown during an exceptionally open winter.

Table 2 brings out several points quite clearly. As in table 1, the cold treatments produced an acceleration of flowering in every variety, even in the 60° F. storage. In general, the lower the temperature the greater the acceleration, but the lowest temperature storage (40°) again produced an undesirable amount of dwarfing not taken into account in table 2. Taking into consideration both acceleration and dwarfing, the most advantageous treatment was that in the 50° temperature, which gave a negligible amount of dwarfing and an acceleration of 2 to 4 weeks over the checks. This, then, is the treatment sought after and the one that has now come into commercial use, namely, a temperature of 50° applied during the last month of the storage season. Subsequent work has modified this procedure but little, the only essential change being to place the planting date about 3 weeks earlier and the subjection to the 50° temperature 2 weeks earlier.

It should be realized that with a large variety of material produced over such a wide latitude, the dates by no means represent the earliest ones at which the early varieties could have been brought into flower. It would have been possible to bring these varieties out of the rooting situation earlier and to give them higher temperature when placed on the benches; but since the purpose was to get comparable behaviors of treated and untreated materials, it was necessary to allow time enough for all to get properly rooted and then to give only such heat as the late ones and the checks could stand. Any other procedure would have necessitated complicated facilities instead of one rooting house and one greenhouse. The lateness of planting in these series of tests is also an important factor in the time of flowering (pl. 2, *A*).

COLD-TREATED DAFFODILS UNDER FIELD CONDITIONS

It is a weird sight to see the hardy daffodils come into blossom in the field in early winter, as has been done frequently in the Carolinas. It is more surprising still when it is realized how rapidly such treated bulbs develop. Field plantings of bulbs cold-treated the last month of the storage season have brought flowers before Christmas and a few by Thanksgiving, as short a time as it is advisable to allow untreated bulbs for rooting as a preparation for forcing into flower under greenhouse conditions.

A bushel of King Alfred large slabs from bulbs grown 1 year on the Arlington Farm were placed in a constant temperature of 50° on August 15 and planted in the field on Arlington Farm from this storage October 15. The winter was exceptionally mild, and the stock made a fine although somewhat dwarfed growth through December and began to blossom January 15. Of course, the keeping quality of the flowers was excellent under the low winter temperatures. The height of flowering occurred about February 15. The planting passed through a temperature of 20° about 10 days before reaching full flowering, but was still in very good condition March 8 when the flowers were destroyed by a heavy freeze accompanied by snow and sleet. Plate 2, *B*, is from a photograph taken February 27.

Such spectacular results would not occur this far north except in the mildest of winters, but such conditions are normal on the Atlantic

coast from the Virginia Capes south, and the production of early flowers in the open or in frames is a demonstrated possibility. For some years the eastern markets have been familiar with daffodil flowers from cold-storage bulbs produced in coldframes from Christmas on. The business is on the increase. This report deals with the King Alfred variety mainly, but Emperor, Glory of Sassenheim, Spring Glory, Victoria, Van Waveren's Giant, and Sir Watkin have behaved similarly in the Carolinas.

VARIETAL REACTION TO COLD TREATMENT

Obviously it has been possible to test the behavior of only a few varieties of hardy daffodils under cold treatment. One of the most interesting comparisons has been mentioned between the King Alfred and Victoria varieties. The latter has withstood long-continued low temperatures much better than the former. While King Alfred bulbs stored at 36° F. for the entire season failed to make appreciable growth of either tops or roots, Victoria bulbs under the same conditions blossomed rather fully. It is true that the blossoms were dwarfed, the vegetative development much reduced, and the roots weak and scattering, but there was development in Victoria bulbs and almost none in King Alfred.

The comparison is all the more striking when it is recalled that King Alfred withstands the vicissitudes of warm climates much better than Victoria. While King Alfred succeeds as a continuous crop as far south in the Atlantic coastal plain as North Carolina, and for a year or two still farther south, Victoria has practically ceased to be grown throughout this entire warm territory. On the other hand, Minister Talma reacts to cold treatment much like King Alfred and is even more resistant to the bad effects of a warm climate, while Golden Spur succumbs to long-continued cold treatment as quickly as King Alfred and is as sensitive as Victoria to the conditions in warm climates. Evidently no generalizations based on the class to which the varieties belong can be made (pl. 1, *A* and *B*).

LOW STORAGE TEMPERATURES DURING WINTER

On November 28, 1929, George Lawler, Tacoma, Wash., put cases of five varieties of daffodil bulbs in cold storage at 33° to 34° F. The writer was present when they were taken out April 5, 1930. They appeared as fresh and bright as when they were put in. A liberal consignment of each of these varieties was sent to the Arlington Experiment Farm and planted in the field in early May. They failed to make either root or top growth. They were taken up the middle of June and placed on shelves in the bulb house, where they remained until September 24, when they were planted in pots and placed on the bench of an unheated greenhouse. The varieties treated were Conspicuus, Minnie Hume, Recurvus, Albus Plenus Odoratus, and Codlins and Cream (Sulphur Phoenix). By November 17 all except Recurvus and Albus Plenus Odoratus, which were just breaking ground, had made an inch of top growth, and by the end of December or shortly thereafter all were of full and normal stature for the size and variety of bulb.

When the stocks came out of storage the flower buds appeared perfect and looked as well as when planted in Virginia in the field in early May. When they were dug in mid-June, however, the buds were all dead. No flowers were produced in pots in the greenhouse the following autumn. Some of the bulbs planted by Mr. Lawler promptly after being taken out of storage, particularly Recurvus and Sulphur Phoenix, made some top growth. This seems to indicate that development the next season may be inhibited by low temperatures during the winter season, although the bulbs appear to keep perfectly.

ROOTING TEMPERATURES

A discussion of rooting temperatures, although exceedingly important, may have but little interest for the householder or the florist who roots his daffodils in out-of-door heeling grounds, because the rooting situations and conditions are natural, generally suited to the rooting processes, and mostly beyond control. But many large forcers today start their bulbs under more artificial conditions on shelves in rooting cellars. Here controlled methods should be adopted, and it is desirable to know what temperatures are best suited.

The subject is too complicated to be more than touched on, since a single set of experiments can be applicable only to the particular date at which the bulbs are planted. If a certain optimum temperature for rooting is demonstrated for this date with normally stored bulbs, the same temperature may not be optimum to bulbs that have been cold-treated. Table 3 presents simple tests that may be taken as a demonstration for midseason.

TABLE 3.—*Influence of rooting temperatures on time of root formation and flowering, under vase culture, in normally stored Minister Talma daffodil bulbs grown in North Carolina, when planted Nov. 17 and benched Dec. 21 at 55° to 60° F.*

Rooting temperature (°F.)	Date roots started	Date of flowering
40	Dec. 18	Jan. 30
50	Dec. 4	Do.
60	Nov. 30	Jan. 20

These tests show that the 60° F. rooting temperature has the advantage both in starting root action and in bringing plants into flower. This does not coincide with recommendations made elsewhere in this circular for a 50° rooting temperature as the optimum. But Minister Talma is an early variety, grown in an early section, in this case planted about the middle of November, 2½ months after September 1, the optimum date for planting for early forcing. Other experiments show that a 60° temperature for rooting of bulbs planted September 1, while likely to start roots earlier than 50°, does not yield flowers either as nearly perfect or as early. This all means that the most advantageous rooting temperature varies with the season. It also varies somewhat with the variety and is influenced appreciably by the storage treatment of the bulbs. A 50° optimum seems to be established for September 1 plantings. In the tests in table 3, 60° produced the best

results, and in many tests it has been shown that 60° is most applicable late in the season (approximately Jan. 1).

In other tests (table 4) bulbs were planted both in vases of water and in flats. All were in ordinary storage to September 28, and checks continued in that storage to planting.

TABLE 4.—*Influence of rooting temperatures on root development and date of flowering of Bellingham-grown King Alfred bulbs cold-treated Sept. 28 to Oct. 12 and planted Oct. 12*

Storage treatment	Rooting temperature	Date roots started	Date tops started	Date of flowering	Storage treatment	Rooting temperature	Date roots started	Date tops started	Date of flowering
°F.	°F.				°F.	°F.			
50	40	Dec. 14	Dec. 21	Jan. 26	Check	50	Nov. 9	Jan. 5	Feb. 1
Check	40	Jan. 4	Jan. 17	Feb. 1	50	[1] 60	Oct. 31	Dec. 10	Feb. 16
50	50	Nov. 5	Dec. 16	Jan. 16	Check	[1] 60	Nov. 4	Jan. 5	Feb. 9

[1] Performance very poor in all bulbs rooted in 60°.

The decided acceleration due to storage and rooting at 50° F. is notable. The bulbs rooted at 40° were accelerated also, but they suffered detrimental dwarfing. The checks rooted at 40° and 50° blossomed together, although the former did not show root development for nearly 2 months after the latter. Buds were just in view in the most advanced of those stored at 50° and rooted at 60° on December 2, when all were moved from the heeling ground onto the benches. Note that they did not flower for a month after the ones cold-treated at 50° and rooted at 50°. It is interesting that the check rooted at 60° blossomed a little in advance of the treated bulbs. The performance of all bulbs rooted at 60° was very irregular and poor. Growth was spindling, flowering irregular, roots were sparse, and flowers were dwarfed. This, in connection with table 3, is enough to demonstrate the complexity of this rooting problem.

LATE FORCING OF DAFFODILS

There is no sharp line of demarcation between early and late forcing, the one passing into the other gradually. Since there may be a difference of 2 weeks between the natural flowering date of southern- and northern-grown stocks, when normally forced early in the season, it is evidently not possible to set an exact date where early forcing ends and late forcing begins. December 1 under some conditions and for some purposes would be a good dividing line; for others the first of the year would be better.

For the earliest flowering early planting is an imperative requirement. It may, therefore, seem paradoxical that the longer the planting is delayed the shorter the time necessary to bring the stocks into blossom. An important requirement of early forcing is a long cool rooting period at a temperature of about 50° F. It is well recognized in commercial practice that better success and earlier flowering are to be expected from the same stocks of daffodils in the northern tier of States than farther south. In warm regions a constant (cold-storage) temperature of about 50° for rooting would be decidedly advantageous, regardless of the storage conditions to which the bulbs have

been subjected. This would obviate some of the difficulties that forcers in warm regions experience in bringing hardy daffodils into blossom.

While a long rooting period of not less than 8 weeks at low temperature (50° F.) is an imperative requirement with normal, early planted bulbs, late in the season no special rooting period may be necessary (pl. 3). As the season advances the period required for rooting and for flowering becomes progressively shortened until about the first of the year, or better, the middle of January, it may be disregarded entirely and the planted bulbs put directly on the benches at a temperature of 60°, or, better still, in the dark at the same temperature if the storage temperatures have been about 50° or approximately root-cellar conditions. This storage does not need to be constant, neither are controlled facilities necessary, for the naturally cool conditions in unheated buildings in the vicinity of Washington, D. C., answer very well. Here again the aim should be to keep the bulbs as close to the magic 50° temperature as practicable until brought into the greenhouse, but the fluctuation may be very great, from 60° to 32°, or sometimes and under some conditions as low as 20° for short periods may be tolerated without injury. On two occasions during this work daffodil bulbs subsequently forced with success in the February–March season went through a temperature of 20° on the bulb-house shelves. Such low temperatures, however, should be avoided and a minimum of about 40° and an optimum of 50° sought.

An explanation of this phenomenon may be necessary. It is a well-known physical principle that pure water under certain conditions may be cooled 1 or more degrees below the freezing point without freezing if it remains perfectly quiet. So with bulb and other plant tissues. Although their freezing points are lower than that of water, they may, if undisturbed, withstand for a short time temperatures below their freezing points without being frozen. The stocks that withstood a temperature of 20° F. without injury in these experiments were in no way disturbed until the temperatures rose well above 32°. In the greater portion of the winter the temperatures fluctuated from 40° to 55° and for short periods up to 60°. These are extreme cases of cold endurance by bulbs, but although not apparently injurious under the conditions, they are to be avoided. Had the bulbs been disturbed at the 20° temperature they probably would have been frozen and killed. The 50° storage temperature is to be approximated as closely as practicable, but a variation of 10° above or below for short periods is safely tolerable.

The time taken to flower King Alfred bulbs at various seasons is well brought out in a series of tests compiled in table 5.

Table 5 is one of the most instructive and interesting compiled from these experimental data. The " rooting cellar " and " dwelling cellar " were very comparable in temperature in their respective seasons, the former running quite constantly at 54° to 60° F. and the latter fluctuating from 56° to 65°, depending on whether the automatic furnace near which the pots were placed was firing. The dwelling in which one lot of bulbs flowered was automatically controlled at 70° to 73° during the day and 60° at night. The bulbs in all cases were held in ordinary bulb-house storage from digging to potting time.

TABLE 5.—*Time taken to flower Bellingham-grown King Alfred daffodil bulbs at various seasons and under different conditions without storage treatment* [1]

Rooting		Date placed on bench [2]	Date of flowering	Days to flowering
Date	Place			
				Number
Sept. 22	Rooting cellar	Nov. 11	Feb. 15	146
	[3]	Dec. 11	Feb. 24	75
	[3]	Feb. 25	Mar. 23	26
Jan. 30	Dwelling cellar	Feb. 21	Mar. 7	36
	[3]	Jan. 28	Mar. 5	36
	[3]	Feb. 6	Mar. 9	31

[1] Bulbs dug at Bellingham, Wash., in early July, cured about a month, arrived in Washington, D. C., early in September, and placed immediately in unheated bulb-house storage.
[2] The greenhouse temperature (on bench) was held at 45° to 50° F. at night to Nov. 28, when it was raised to 50° to 55° and after Christmas to 55° to 60°.
[3] Not placed in rooting or dwelling cellar.

The significant figures are in the last column, where it is shown that the lots planted the latter part of January blossomed in 36 days; those planted about the middle of December took twice as long, and those potted the latter part of September took four times the number of days to flower. The flowers produced would pass for normal except under the most careful comparisons, which would show a slight dwarfing in the late plantings. The stems and leaves are likely to be shortened somewhat in the bulbs forced rapidly late in the season, although this is an advantage when they are planted in pots.

The development of a copious root system in the flats and pots is and always has been the criterion for judging when normally treated daffodils should be brought into the greenhouse. Such a root system is imperative for successful flowering of early-planted bulbs, but when the stocks are held dormant until late in the season the rooting factor does not seem to operate. The bulbs at this season develop tops and roots at the same time, like the Paperwhites (Paperwhite Grandiflora). They are put into a temperature of 60° F. immediately on planting and flower acceptably with only 1 or 2 inches of root growth. It seems incredible to one accustomed to a "pot full of roots" before forcing that such acceptable flowers could be obtained from such poorly rooted plants.

It should be realized that all of these manipulations, the cold treatment, late storage, and even the ordinary forcing process itself, have dwarfing tendencies which become more pronounced as the treatments deviate from the natural conditions of development in the open ground. The producer of daffodil flowers out of season must aim to vary his conditions just enough to get the desired results without intolerable dwarfing.

Dwarfing tendencies are very evident in the quick, late forcing of daffodils and are shown most prominently in the roots (pl. 4, *A* and *B*). These tendencies are evident in the vegetative structures, especially in length of stem and leaves, and occur to a lesser degree in the flowers, which, however, are not seriously affected. Indeed, it is considered that these dwarfing tendencies are decidedly advantageous for the plants in pots, since such varieties as King Alfred are rather leggy for pot plants if forced in the ordinary way. Reducing the length

A, Sir Watkin daffodils, Bellingham grown, potted from normal storage January 28, rooted in a constant temperature of 50° F. to February 18, then put on the bench at 60° to 65° at night; began to open March 6; photographed March 8. *B*, King Alfred daffodils, Virginia grown, from normal storage, planted February 11, opening March 1; photographed March 9. Carried on bench at 55° to 60° night temperature from planting.

A, Left, Van Waveren's Giant daffodils (double nose); right, King Alfred (single nose); Bellingham grown, held in normal storage from digging to October 14, then in a constant temperature of 40° F. to planting January 28, rooted in a constant temperature of 50° to February 18, and then put on the bench at 60° to 65° at night to flowering March 3; photographed March 4. Note the short roots. *B*, King Alfred daffodils, Virginia grown, from ordinary cool bulb-house storage, planted in water February 4 and carried on the greenhouse bench at 55° to 60° night temperature to February 14; transferred to kitchen table for 3 days when sheaths began to crack; then retarded in dark cool cellar for 5 days and returned to the kitchen to open for an exhibition March 7; photographed March 9. Note the short roots.

of stem and leafage enhances their ornamental value when used in the pots in which grown.

Custom has established an early planting practice for the flowering of daffodils under glass, and it is not commonly realized that the bulbs may be kept dry in good condition to April if wanted that late. All that is necessary is to keep them cool and dry enough to prevent rooting. They may even be planted outside in April to flower with shortened stems in May. If the bulbs are sound and of first quality there is no difficulty in preserving them for such late planting.

The advantage of late planting is considerable. It is an adjunct but not a substitute for early planting. It makes it possible to successfully introduce the forcing of hardy daffodils into the home in much the same way as Paperwhites are used early in the season. This can be done after about December. The development of a business of this kind should increase the consumption of the bulbs and thus enable the dealer to dispose of surplus stocks late in the season after the regular trade has been supplied.

Late forcing furnishes a rather certain method by which the grower may be able to supply potted daffodils or cut flowers for the Easter festival. Early-planted bulbs often cannot be held back for Easter. If, however, the bulbs are kept dry and cool they need not be planted until 3 or 4 weeks before blossoming is desired, thus assuring a supply without occupying bench room for more than 4 weeks, or, better, but 2 weeks, if rooting is done for that length of time in the dark at 60° F.

DAFFODILS IN VESSELS WITHOUT DRAINAGE

The hardy daffodils are not generally considered suitable subjects for forcing in undrained vessels in the home. Paperwhites and Roman and Dutch hyacinths are the favorites for this kind of treatment. Indeed, they are not forced much in the home in any way. The early daffodils, however, are not uncommonly attempted in sphagnum, peat, or pebbles, but are often unsuccessful when planted at the usual time in autumn. The reason that the Paperwhite is so popular for this kind of handling is due in large measure to its rapid development, only 8 to 10 weeks being necessary to bring it into blossom when potted from September 1 on.

Table 5 shows that it took nearly 5 months to bring King Alfred into blossom from potting September 22. This is too long to carry bulbs in good condition in vessels without drainage. It can be done, but more care is required than the householder is willing to bestow. On the other hand, it is shown in the same table that bulbs held in good storage to the first of the year or later may be flowered in about 2 months, and when held in similar storage a month later may be flowered in about 4 weeks from planting. The most promising procedure for vase forcing of daffodils, therefore, is to hold bulbs dormant and cool until late in the season (December, January, or later) when they may be forced along with a temperature of 60° F. from the time of potting.

It is surprising how rapidly the stocks come into flower late in the season, and there is but little difference in the time required to bring in the late and early varieties. Some blossoming not infrequently

occurs in 15 to 20 days, and a month's time is ample in February (pl. 5).

The behavior of the stocks in vase culture is very similar to that discussed under the general heading of Late Forcing of Daffodils. There occurs the same sort of dwarfing, especially of plant and roots, the latter becoming only 1 to 2 inches long (pl. 4).

In vase culture there is a tendency for the roots to fail toward the time of flowering, especially if planting is done early enough to require as long as 2 months' time for the flower to appear. To obviate this, frequent changing of the water is necessary, but the plants go on growing and blossom even when the roots slough off. A very little potassium permanganate added to the water seems to assist somewhat in keeping the roots in better condition.

It has been the writer's practice in vase forcing to change the water on alternate days. The bulbs are taken out of the containers and held under a tap with good pressure. If there is an accumulation of scum on the base it may be rubbed off gently with the tips of the fingers. The phenomenon is no different from that occurring so often in the vase forcing of hyacinths, and the odor resulting from neglect is just as offensive. Careful attention to changing the water will obviate the trouble and keep the roots functioning until blossoming occurs.

Prime-quality daffodil bulbs are necessary for vase forcing, the same as with hyacinths. They should be sound and dormant up to the time of planting. It is a good plan to clean the bulbs well before planting them. The old loose scales should be brushed off and the bases cleaned of all the accumulated refuse which so commonly occurs there.

Bulbs forced in this manner, and indeed any late-forced bulbs, are of little value after such treatment. It is best to discard them, for it will take 2 or 3 years of good culture to bring them back to normal.

While it is perfectly feasible to put the bulbs in full light immediately after planting, better results will usually be secured if they are put in the dark at a temperature of 60° F. Most of the home experimental forcing in these investigations has involved placing the vases for a short period in a furnace room where the temperature may fluctuate from 54° to 65° but is close to 60° most of the time. They remain here for varying periods of 2 to 3 or 4 weeks, preferably until the scape is 2 to 4 inches high, and are then transferred to the living room, where the temperature is automatically controlled at 70° to 73° in the day and 60° at night. December planting may require 4 weeks in the cellar, but late January and February plantings only 2 weeks or less.

These conditions may seem rather exacting. Fortunately, so far the measure of the requirements is better gaged from exact experimental conditions, although successful forcing will be had with nothing more serious than a few days' difference in time of flowering even when conditions are somewhat variable. In short, the hardy daffodils are no more difficult to flower in vases without drainage from January to March than are Paperwhites planted in September.

PAPERWHITES

The reaction of Paperwhite bulbs to low storage temperatures differs decidedly from that of the hardy daffodils, since storage much

A, Early Perfection daffodils, Bellingham grown, from ordinary but cool storage, planted February 11 in sphagnum, first flowers opening February 24, retarded from February 27 to March 9, and carried on the bench at 55° to 60° F. from planting to flowering. The flowers shown are the second crop; the first has been cut. *B*, King Alfred daffodils, forced in vases of water; left to right: North Carolina grown, flowered between February 4 and February 28; Washington grown, flowered between February 11 and March 6; Virginia grown, flowered between February 11 and February 28; Virginia grown, flowered between February 11 and March 6. Virginia and North Carolina grown bulbs were retarded to be photographed March 8. All were carried on the greenhouse bench at 55° to 60° night temperature from time of planting to flowering.

below 80° F. for any length of time usually results in impaired quality. Paperwhite bulbs will produce normal blossoms after 2 or 3 months in storage at 80°. A slight acceleration in blossoming has resulted when the bulbs were put from 80° into a lower temperature for a short period before planting, but the reaction has not been distinctive enough to warrant general recommendations for either commercial or household uses.

EARLY FORCING OF BULBOUS IRIS

Acceleration of the flowering of bulbous iris of the Spanish and Dutch groups does not differ essentially from that of daffodils. In warm regions the bulbs are held in ordinary storage to the end of July, but in cool ones the temperature during this period had better be raised to about 80° F. They should be kept at 50° during August and then potted, but are put directly on the greenhouse benches for rooting instead of in a cool situation. In the Virginia section, where the investigations have been conducted, the natural temperatures run high in September, it often being impossible to keep the unheated greenhouses below 80° in the middle of the day and frequently 90° occurs for short periods.

In the storage treatment of bulbous iris for forcing there seems to be a decided benefit from an initial period of high temperature. A constant temperature of 80° from digging to August 1 has given good results, but flowering for Christmas is practicable with Wedgewood bulbs grown at the Bellingham Bulb Station when kept in natural storage to the end of July and at 50° during August.

On the whole, Wedgewood reacts to cold treatment the most readily of any variety tried. Since its flowering with temperature manipulation and under normal storage covers the season up to the natural flowering of the earlier of the Dutch varieties, there may be but little need for the acceleration of the flowering of the latter. However, these varieties react similarly, since a half dozen tried have blossomed 2 to 4 weeks ahead of the untreated checks.

Wedgewood bulbs held in normal storage to August 1 and then in 50° F. to December 15 have blossomed nicely in late January in vases of water precisely as hyacinths are forced. It is possible to flower them in vases from September 1 planting, but the period is too long at that season and the demands for attention too critical for the average householder to attempt. The constant temperature of 50°, however, is not necessary for their vase handling after about December 15, because the advancing season and the natural cold of normal storage have the desired effect of shortening the time required to flower them.

At present it is not practicable to set the earliest date at which Wedgewood bulbs may be flowered, because of the many factors entering into the problem. Of importance are date of digging, temperature of storage up to August 1 and from August 1 to planting, and temperature of the greenhouse during the forcing period.

In some early tests made in these studies, Bellingham-grown Wedgewood iris bulbs were subjected to low humidity at a temperature of 80° F. from digging July 7 to July 30, then shipped to the Arlington Farm by express and put in a temperature of 50° from August 15 to September 25, then flatted up and put on the benches of the greenhouse, where they were carried with maximum ventilation

but without artificial heat until early November, when the temperature was prevented from going below 40° at night. The treated stocks began to flower November 16, and the flatted bulbs were in full blossom the day before Thanksgiving. The check flats of untreated bulbs were handled exactly like the treated ones up to the flowering of the latter, then continued at 50° to 55° night temperature to early January, and then 55° to 60° to blossoming January 15. The treated bulbs thus flowered about 48 days earlier than the normally stored ones.

It should be realized that Bellingham-grown iris bulbs are late maturing; Carolina or Virginia grown stocks can be brought into flower earlier. Commercial growers in the vicinity of Wilmington, N. C., have cut flowers from cold-stored Wedgewood bulbs the end of the first week in November. They use normal storage through July, 50° in August, and pot in early September.

The humidity of the chamber for cold treating of bulbous iris is of even more importance than for the treatment of daffodils. The control of humidity entails an additional expense which is not commonly provided in commercial cold-storage establishments. However, the matter is not so difficult to arrange, for all that is necessary is to keep the bulbs from rooting.

In most sections in the North and even in northern Virginia little attention may need be given to the humidity if the aeration is good; that is, the natural humidity of a chamber cooled to 50° F. is satisfactory if the air is circulated. But the bulbs should not be stored in masses, and provision should be made for air circulation by fans, blowers, or other means. In excessively humid sections with the atmosphere near the saturation point at 85 to 90 percent in the middle of the day much can be done to keep down humidity in the chambers by keeping up the circulation and minimizing the introduction of outside air by keeping doors closed as much as possible. Even in humid sections prevention of rooting can be accomplished by these means and a treatment given without dehumidifiers in the chambers.

SUMMARY

Cold treatment of daffodil bulbs when applied throughout the entire storage season causes decided acceleration of flowering, but intolerable dwarfing. The lower the temperature the more pronounced is the effect up to complete inhibition of growth in the early trumpet varieties at about 36° F.

Daffodil bulbs cold-treated at low temperatures (33° to 34°) for long periods during late autumn and winter have failed to grow in the spring, although apparently in a perfect state of preservation. The flowers died shortly after coming out of storage, but the bulbs grew normally without flowers the following autumn after passing the summer dormant in ordinary storage.

Daffodil bulbs stored at low temperatures during the entire storage season to inhibit fall rooting and growth have grown in late winter after 3 months in moderately warm storage (60°).

A variation was found in the resistance of different daffodil varieties to low storage temperatures, King Alfred, for instance, being detrimentally affected sooner than Victoria.

Moderately cool temperature (50°) applied during the last month of the daffodil storage season produced an acceleration of 3 or 4 weeks in flowering without detrimental dwarfing.

The best practical procedure and the one now commercially followed for daffodils is to employ common warm storage to the first of August and then a constant temperature of 50° up to potting about the first of September.

It seems to be necessary with daffodils to allow a considerable growth of the bud before the cold treatment, the degree of this development being conventionally expressed by an expansion to visibility by the unaided eye which, however, is not always easy to evaluate. Cold (50°) applied after this development has taken place, about August 1, seems to produce the most desired effect.

Generally the normal shed storage conditions in the section in which the daffodil bulbs are produced are fairly well adapted to the preliminary development of the bud. However, if such temperatures are below about 70° much of the time, additional warmth may be advisable.

The cold treatment of daffodil bulbs accomplishes the shortening of the time needed to bring them into blossom from 4 or 5 months to 3 or 4 months when potting is done in early season, to 2 months when it is done in midseason, and to 1 month when done in late season. It may also increase bulb sales, assist in the disposal of surplus stocks, and insure flowers for the Easter festival.

Daffodil bulbs for late forcing (potting after Dec. 1) are best held at root-cellar temperatures (40° to 55°) and kept dry up to the time of planting. Warm storage during this period seems to retard flowering.

The earlier the daffodil stocks are dug the earlier they may be flowered, and a measure of acceleration may be obtained in any section by a 2 or 3 weeks' premature digging which will result in acceptable inflorescence but less firm bulbs.

The principles stated in the paragraph above, together with the additional demonstrated fact that daffodil bulbs may be grown much farther south 1 year than it is practicable to produce them continuously, are suggestive of the possibility of producing high-class bulbs in cool regions and transferring them to warm ones for a season in order to gain a measure of earliness.

The hardy daffodils may be flowered like hyacinths in vases of water or other vessels without drainage after about the first of the year if the bulbs are held at root-cellar temperatures to date of planting.

Allowing 8 to 12 weeks for the development of a copious root system is an imperative requirement when daffodils are potted early, but as the season advances the time for rooting may be progressively curtailed until after the beginning of the year, when the potted bulbs may be subjected directly to forcing temperature of 60° to flower in from 60 to 30 days.

Optimum rooting temperatures for forcing daffodils have not been sufficiently checked, but seem to be higher than commonly stated. The best results appear to have been secured in these experiments at about 50° when planting is done September 1. From about January 1 on, 60° may be endured.

When daffodil bulbs are held in cool storage and potted from January on, there is but little difference between the date of flowering of the late and the early forcing varieties.

Dutch and Spanish iris bulbs react to a 50° temperature during the month of August very much as daffodils do; but even when planted September 1 they are put directly on the benches in a well-ventilated house. They are decidedly benefited by a preliminary heat treatment (80°) from digging time to August 1. Wedgewood is especially recommended for these treatments. Its flowering may be hastened from 4 to 6 weeks without detrimental dwarfing.

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